POTENTIAL GROUND AND SURFACE WATER IMPACTS ASSOCIATED WITH THE USE OF ETHANOL AS A FUEL OXYGENATE

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Briefing to the California Environmental Policy Council

Sacramento, California
January 18, 2000

Potential Ground and Surface Water Impacts – Introduction

- What we did to evaluate potential ground and surface water impacts associated with the use of ethanol as a fuel oxygenate:
  - Began the development of comprehensive life-cycle model.
  - Performed literature reviews of transport and fate of ethanol and benzene in the presence of ethanol.
  - Used screening models to evaluate ground and surface water impacts.
  - Evaluated chemical analysis techniques used to measure ethanol in the environment.
  - Examined the environmental properties of alkylates.
  - Submitted our findings to peer review.

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Potential Ground and Surface Water Impacts – Release Scenarios

- Release scenarios were developed based on the production, distribution, and use of ethanol as a fuel oxygenate.
  - Not all release scenarios were evaluated.

- In the time allowed, the following scenarios were evaluated because they were most likely to have impact:
  - Leaking under ground fuel tank releases.
  - Rail tank car release to a river.

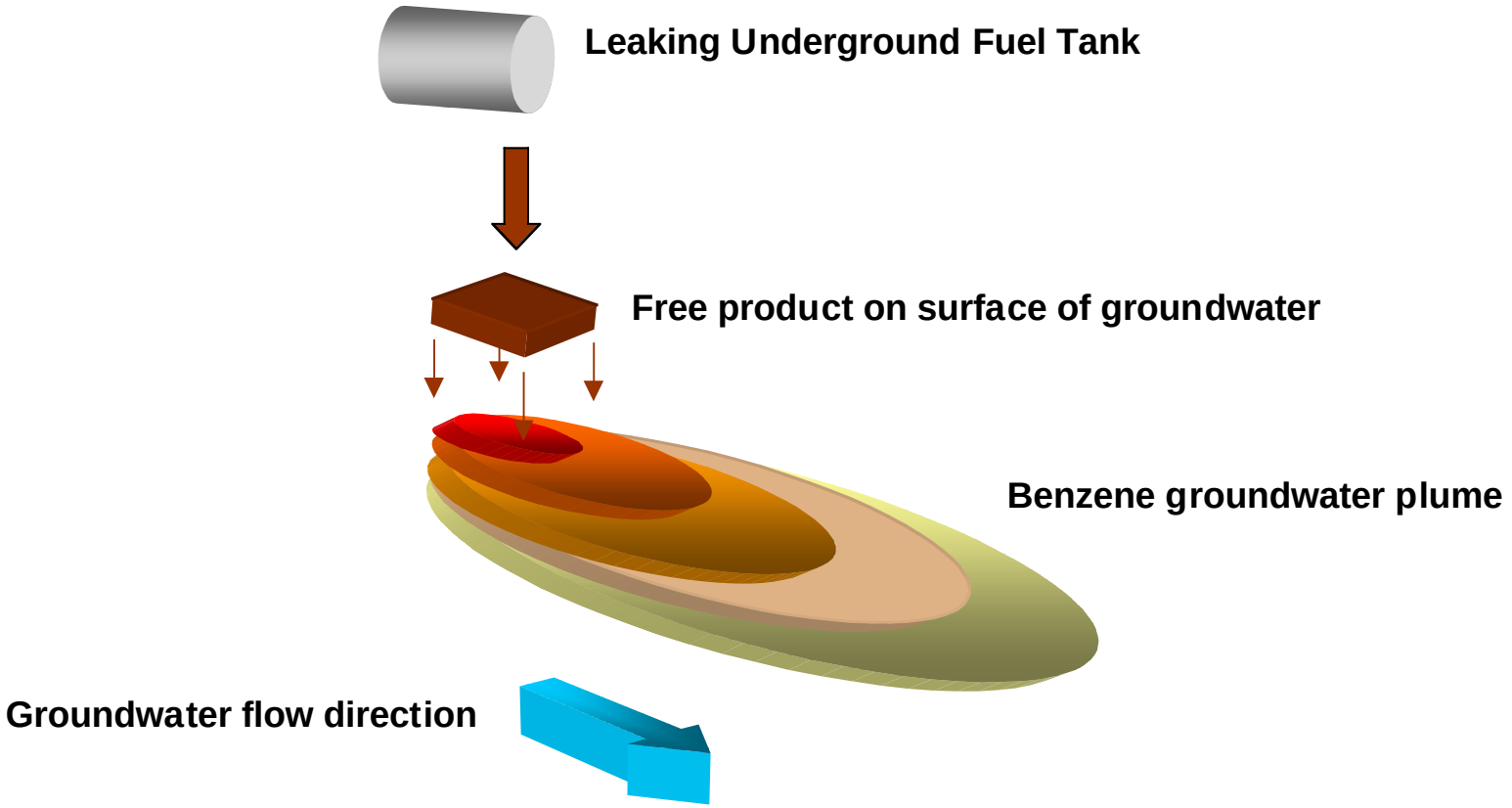
Potential Ground and Surface Water Impacts – Ethanol Transport and Fate

- The impact of ethanol co-solubility effects on benzene dissolution will likely be very minor.
- Ethanol is degraded very rapidly in soils and water.
  - Degradation half-life in ground water ranges between 1.3 and 7 days, depending on electron acceptor used.
  - Degradation half-life in surface waters is about 3.5 hrs after about a 10-hr lag.
- The preferential degradation of ethanol in groundwater may result in longer benzene plume lengths.

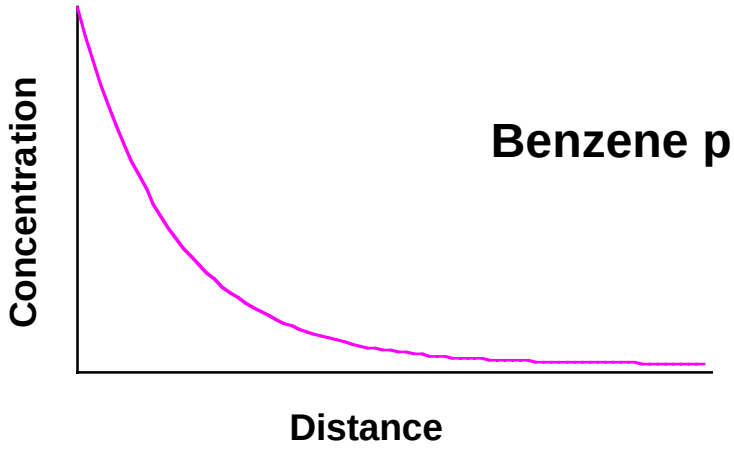
Potential Ground and Surface Water Impacts – Modeling of Benzene Plume Lengths

- How long may the benzene plumes increase if ethanol is used?
  - Three independent screening model assessments indicate that average benzene plumes may increase 24 – 33 % in the presence of ethanol.
- These models make two important simplifying and conservative assumptions:
  - Benzene is not degraded in the zone where ethanol is being rapidly degraded.
  - The biodegradation rate for benzene is uniform over the length of the benzene plume.
- If these assumptions are not representative of actual processes, then benzene plume lengths may be shorter than estimated by the screening models.

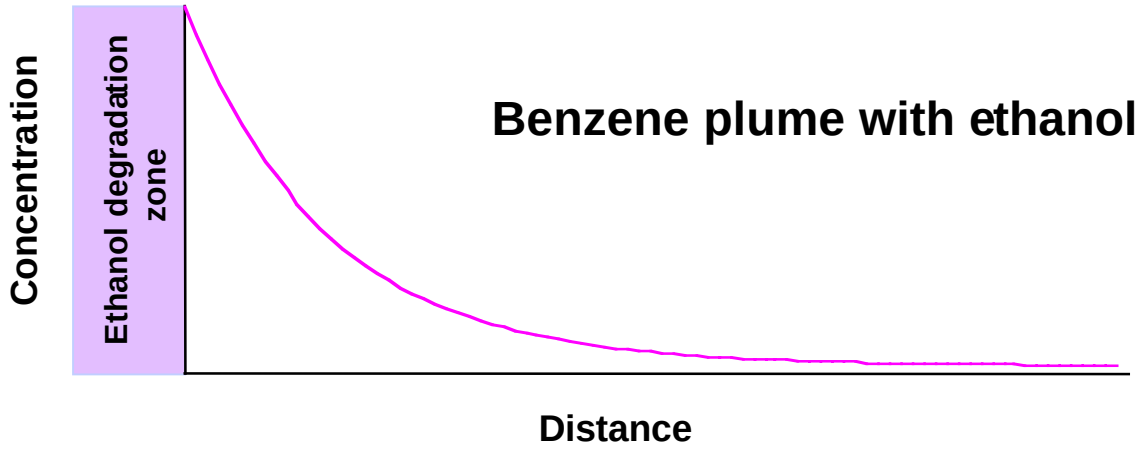
Potential Ground and Surface Water Impacts - Plume Conceptual Model



Potential Ground and Surface Water Impacts - Plume Conceptual Model (Cont.)



Benzene plume with ethanol absent.



Benzene plume with ethanol present.

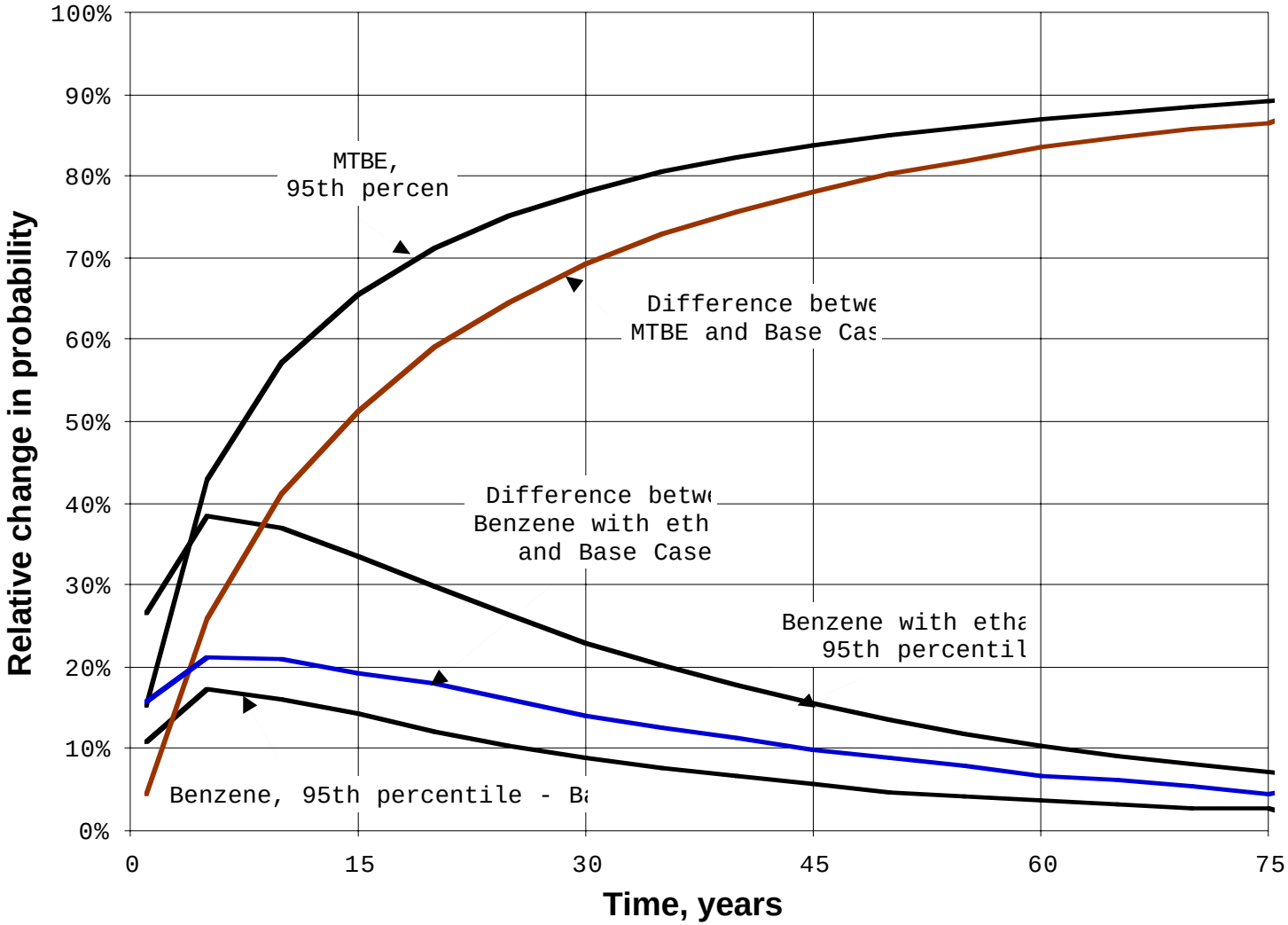
Potential Ground and Surface Water Impacts – Modeling of Benzene Plume Impacts

- What is the comparative potential impact of increased benzene plume lengths relative to MTBE?
  - A baseline potential impact was developed for benzene without ethanol present.
  - This baseline was used to compare the impacts of MTBE plumes and benzene plumes with ethanol present.
- Step 1. A baseline population of benzene plume lengths without ethanol was modeled.
  - This population compared well with a population of 500 measured historical case benzene plume lengths.
  - For the population of benzene plumes modeled, plume lengths were forecast over a 100-year period.
  - Twenty-one time intervals were used and 4000 plume lengths were developed for each time interval.

Potential Ground and Surface Water Impacts – Modeling of Benzene Plume Impacts

- **Step 2. Relative location information for public drinking water wells and all known active leaking underground fuel tank sites in California was used to perform an impact analysis.**
  - **For each LUFT site in California, the distance between every known drinking water well within 30,000 feet of the LUFT site was calculated.**
  - **Based on the population of modeled plume lengths, the probability of a benzene plume reaching drinking water wells near each of these LUFT sites was calculated for each time interval.**
- **Step 3. These first two steps were repeated for MTBE plumes and benzene plume in the presence of ethanol.**
- **Step 4. A series of relative probability curves were prepared.**

Potential Ground and Surface Water Impacts – Modeling of Benzene Plume Impacts (Cont.)



Potential Ground and Surface Water Impacts – Measured Benzene and MTBE Impacts

- What is the current measured benzene and impact rates?
  - The average annual percentage of public drinking water sources that are impacted from all sources, including LUFTs:
    - Benzene = 0.35%
    - MTBE = 1.17%
- A caution:
  - Our comparative analysis is not intended to be predictive in any regard.
  - It is a screening analysis that is intended to show a relative comparison between MTBE and benzene in the presence of ethanol.

Potential Ground and Surface Water Impacts – Surface Water Impacts

- Impacts of ethanol-containing gasoline on surface water resources were also evaluated.
- The loss mechanisms for MTBE and ethanol from surface waters is different.
  - Ethanol is removed through biodegradation.
  - MTBE is removed through volatilization at the water's surface.
- The toxicity of ethanol is about 2000 time less than MTBE.
  - If there are spills of equal mass, MTBE will have much greater impact to surface water drinking supplies.
- Washout of ethanol from the atmosphere through rain may be 40 times greater than MTBE.
  - Ethanol concentrations in rain could be about 40 to 65 ppb.
  - Ethanol will be rapidly removed from rainwater through biodegradation.

Potential Ground and Surface Water Impacts – Use of Alkylates

- Alkylates are complex mixtures of branched hydrocarbons with octane ratings close to 100.
- Significant quantities of alkylates are already present in gasoline.
- Compared to MTBE, less ethanol is required to meet a specified oxygen content in gasoline.
  - The resulting octane deficit may be compensated by adding additional alkylates to gasoline that contains ethanol.

Potential Ground and Surface Water Impacts – Properties of Alkylates

- Aklylates have:
  - Low solubility in water.
  - Lower density than water.
  - High volatility.
  - Low mobility in soils.
- Properties like biodegradability or toxicity are not easily extrapolated to all alkylate compounds.
  - Cancer risk, reproductive and developmental effects have not been studied.

Potential Ground and Surface Water Impacts – Conclusions

- **The water resource impacts associated with the use of ethanol will be significantly less and more manageable than those associated with the continued use of MTBE**
  - **The key factor is the biodegradability of ethanol compared to MTBE.**

- **An important question before the Council is "Will additional information change the decision to use ethanol as a fuel oxygenate or not?"**

Potential Ground and Surface Water Impacts – Recommendations for Future Research

- If a decision is made to use ethanol as a fuel oxygenate, several additional analyses and experiments should be performed to help manage its use.
  - A complete life cycle analysis should be performed.
  - Experiments should be performed to evaluate the degradation of benzene by ethanol degrading microbial populations.
  - Field and laboratory studies should be performed to evaluate changes in benzene degradation rates over the length of a benzene plume.
  - A series of field sites should be identified and studied to support modeling assumptions.
  - The chemical analysis techniques used to measure ethanol in field samples should be refined to lower limits of detection.
  - Additional historical case data should be collected and analyzed.